KEPCO POWER SUPPLY news

Latest information on the development and application of Voltage/Current Regulated Power Supplies.

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KEPCO-MIDWEST SEMINAR ON TOUR

Midwest's Bernie Menarik discusses the programming capabilities of the basic Kepco Control Bridge with a seminar group.

Midwest Electronic Sales, Kepco's representatives for South Wisconsin, Eastern Iowa, Northern Illinois, Indiana, and Kentucky, has developed a very successful "on the spot" in-plant Kepco Seminar program. Although recently inaugurated, these seminars have already achieved considerable popularity with the many industrial, electronic and research firms in Midwest's area. It brings to interested technical audiences the latest operational control techniques developed by Kepco which range far beyond the front knob control limits most commonly associated with the use of power supplies. The lecture material, based on the Kepco Power Supply Handbook, is presented in a clear and informative manner, and has proven very useful to engineers and technicians. In fact, several universities have responded very favorably to these Midwest-Kepco Seminars.

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NEW HIGH-VOLTAGE OPERATIONAL POWER SUPPLY/AMPLIFIER

In the new BHK Series High Voltage Power Supply/Amplifier, Kepco has chosen to use a fully dissipative regulator design. Although this requires more pass elements and greater heat dissipation, by avoiding the use of any preregulators, the power supply is made much less restricted in terms of bandwidth, dissipation, and output range. One kind of preregulator used previously to limit dissipation in Kepco's own HB design, relied on the selection of secondary taps on the power transformer to keep the voltage across the pass element minimized. Primarily, the objective, in the case of the HB design, is to keep the *dissipation* minimized where the pass tubes are able to take the *voltage*. Other design methods, include variable auto-transformer tracking, as in the HB 2050 and the HB 2500 power supplies, (in which the purpose is to keep the voltage within the capabilities of the pass tubes).

All of these methods of preregulation or dissipation control, in some way limit the flexibility of the power supply. Other

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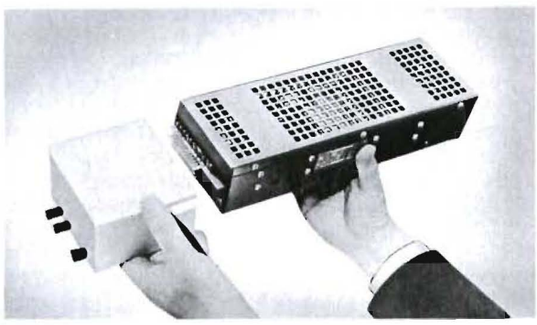
THE HI FI POWER SUPPLY

Need an audio amplifier? Faced recently with a requirement for a small public address amplifier, Kepco engineers decided to see what would happen if they hooked a microphone or phono unit input to one of the new, fast slewing DC power supplies. The results: beautiful music! The Hi Fi Power Supply, as it is known, has been traveling ever since, serving as the PA amplifier for Kepco's lecture series (on the "Op-Amps . . . with muscle," see *EEE Magazine*, June, 1966).

This vocal power supply has elicited many questions from audio-minded engineers that we hope this close-up view will help answer and, perhaps, inspire others. We have no illusions that fast slewing power supplies should be promoted as audio amplifiers, but the bandwith-gain so illustrated is indicative of the variety of instrumentation tasks that can be handled by such equipment.



MICROPHONE PRE-AMP PLUG-IN ATTACHMENT WITH MODEL PAX 7-1CHS POWER SUPPLY

The versatility of which we speak derives from the power supply's ability to be easily modulated; that is, to have its output varied as a linear function of input or command signals. All of Kepco's programmable DC supplies have this capability. They may be modulated by a changing resistance/voltage/current and/or conductance, and like operational amplifiers, can be made to respond in specific, predictable ways to such excitation. Dynamically, the usual power supply's output and feedback filter-capacitors severely limits the bandwidth of signals that can be accommodated. For practical purposes, the conventional power supply is limited to quasi-static programs whose dynamic rate-of-change does not exceed a few hundred volts per second.

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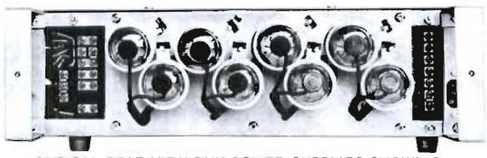
HIGH VOLTAGE POWER SUPPLY/AMPLIFIERS

Continued from Page 1 - Col. 1

methods which have been used include "the piggy back" design, (with similar limitations), and switching preregulators, which are semi-conductors in low level voltage circuits, switched on and off at various frequencies. This technique produces non-harmonic frequency components in the output, however, which are disadvantageous.

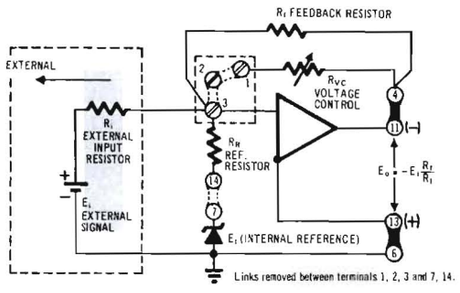
All of these techniques depend on "trading off" one performance feature for another. We have chosen in the new BHK design, a fully dissipative route, in which we do not "trade off" any performance at all. Instead, we have dealt directly with the problem of heat dissipation, rather efficiently by using vacuum tube pass elements which operate at high temperatures. The heat transfer problem is considerably less than with transistors, where the temperature differential between the dissipating element and the outside temperature would be relatively small.



TYPICAL REAR VIEW BHK POWER SUPPLIES SHOWING PASS AND CONTROL TERMINALS.

The type 8068 pass tube is particularly well designed for this kind of service. It has a 3500 volt plate to cathode rating, a 35 watt plate dissipation rating, 5200μmhos trans-conductance, and yields very high gain. As a matter of fact, the tube gives so much gain in this particular circuit that the overall loop gain approaches 120 db, (although the closed loop gain is only specified as >100db). This means that although the power supply's temperature compensated six volt reference is amplified up to the 500, 1000, or 2000 volt output level, (the operational gain, or amplification is better than 83,167, or 333 times, respectively), the remaining, so-called "loop gain", which determines the regulating capability, will still exceed 60 db. In order to have a well-regulated high voltage power supply, it is obviously necessary to have very high gain circuits.

Rather than letting all this gain go to waste, we have designed the BHK power supply so that there is convenient access to all the necessary control points in the circuit. The gain can be used as though it were an amplifier, with a signal applied to a pair of input terminals, and an output taken from



TYPICAL BHK OPERATIONAL AMPLIFIER CONFIGURATION.

another pair. The BHK, then, is a unipolar, high voltage DC amplifier.

We have made provision for *fast slewing connections,* in which the filter capacitors, that are normally used when the power supply is functioning as a power supply, can be removed. The bandwidth of the unit without the filter capacitors is large enough so that the power supply is extremely useful as an instrumentation amplifier.

For example, from the chart that is reproduced elsewhere in this issue, a 500,000 volt/second slewing rate with a 100 volt peak to peak wave form is capable of 1.6 kc bandwidth, and at the 10 volt peak to peak level, 16 kc. For a 1 volt peak to peak excursion, the bandwidth is increased to 160 kc. This is a sufficiently wide bandwidth to make the device useful in signal following and processing applications, and as a quick responding current source, among other possible applications.

When the power supply is operating as a current source, it is effectively self-programmed. Its voltage will follow the load resistances in an automatic fashion. Therefore, the user has to think in terms of the slewing rate of the output to determine what the recovery time of the device would be as a current regulator. In this case, the recovery time would be better than 0.5 volt per microsecond.

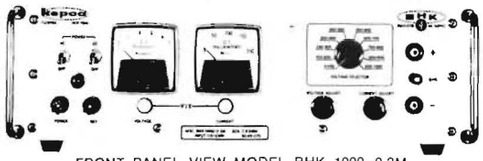
As a power supply, fast programmed from one voltage level to another throughout its range, the ability to get to a new voltage, and settled at that voltage, is enormously improved by this fast slewing capability. It is possible to step from 0 to 1000 volts, for example, in <2 milliseconds. This by comparison, might take 4 seconds, if the power supply were functioning with its normal output capacitor.

The settling time is a function of the damping ratio of the power supply. Provisions are made to set it up for an underdamped, overdamped, or critically damped response. The method that has been provided takes the form of an adjustable feedback capacitor in parallel with the voltage control. Assuming a 1 milliampere control current, a selection of fixed ceramic capacitors, from 50 to 3900 picofarads is provided. These can be connected in parallel in various combinations. The range of feedback capacitance is such that it is possible to set the power supply either for an underdamped state (in which the output voltage overshoots its final value, oscillates once or twice about the ultimate value and then settles down), a critically damped state, or a considerably overdamped state in which the voltage approaches its final value in an asymptotic fashion. The maximum programming speed occurs when the system is somewhat underdamped, and overshoots perhaps once, and then settles back to its final value. This relationship is treated in many textbooks on servomechanisms or feedback control systems.

The BHK power supply is also an automatic crossover power supply. Because of its full dissipation capability, it has the ability to operate as a current regulator from zero to its maximum rated output voltage, without any current derating restriction. Consequently, Kepco has built in the automatic crossover circuit. In effect, we have built-in a full ampifier to detect the voltage across an internal current sampling resistor, producing a signal proportional to the output current. There is a complete gate circuit which allows the pass tubes to choose between the signal from the voltage amplifier and the signal from the current amplifier. A VIX* circuit in the power supply displays the position of the gate on the front panel, and also provides a signal at the rear. In this power

supply, the VIX* signal is 115V AC.

Like all of the Kepco automatic crossover power supplies, this one contains a pair of output controls on the front panel, a ten-turn voltage control, and a ten-turn current control. Since the voltage control must cover a relatively wide voltage range, a ten position range switch and ten-turn vernier control is provided. In the case of the Model BHK-1000-0.2M, the range switch has ten steps of 100 volts per step, and the 10-turn control need only cover a 100 volt span. The current control does not have this kind of problem, since it has only a few hundred milliamperes of range, and is adequately covered by a single 10-turn control. The voltage control's step selector does not limit the programming of the power supply. The switch is there for the purpose of increasing the resolution in the setting of the output voltage and also to circumvent the problem of supporting all the output voltage across a single control. Since all resistors have a voltage coefficient, that is to say, their resistance changes as a function of the voltage being supported across their terminals, it is desirable to keep that voltage small, and this the ten position switch accomplishes. The switch is *not* doing any switching in the *primary* or the *secondary* of the transformers. It is *not* in any way limiting the dissipation inside the power supply, and so it has *no limitation* on the programming function of the power supply, or on its range of operation as a current regulator.



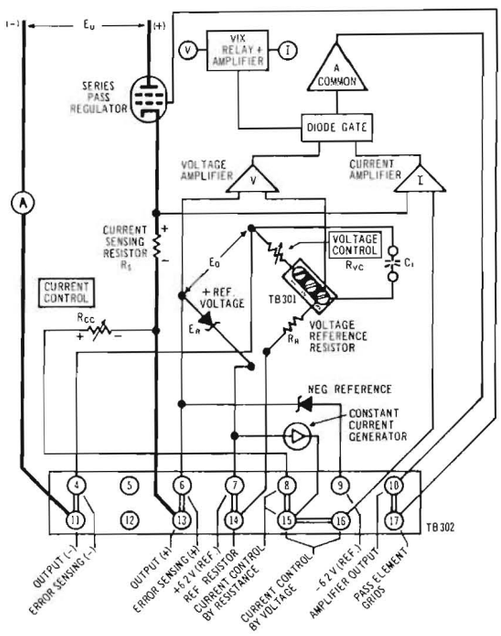
FRONT PANEL VIEW MODEL BHK 1000–0.2M

The front panel output connectors on the BHK are specially designed for safety. They are recessed, so that all accidental contact can be minimized. All the programming function and output terminals are, of course, provided on the back of the supply, behind lucite safety panels.

The controls which are provided on the BHK power supply are unique in the power supply industry for their completeness and variety. In addition to the front panel voltage controls and current controls, the designers of this power supply have built into it primary offset compensation controls, which recognize the existence of offset ratings, and their importance. These offset controls enable the user to precisely zero all of the non-idealities of the amplifiers.

Non-idealities can briefly be divided into two parts; the fixed parts of the offset voltage, and the offset current. In the BHK, there is an offset voltage adjustment having a plus-minus 120 millivolt range. It is a 25-turn trimmer built into the power supply. There is an offset current compensator having a 0-12 microampere range, which will zero the offset current into the voltage amplifier. There are a pair of calibrators, which effectively set the control current, one for the voltage amplifier, having a plus-minus five percent range, and the other for the current amplifier, again having a plus or minus five percent range. Both of them are 25-turn trimmers.

There are two adjustable AC lag networks, which provide for AC stability, when the output filter capacitors are unstrapped for fast slewing operation. With the removal of the capacitors, the phase gain margin of stability is greatly reduced. To operate without the output capacitor, it is necessary to work into a purely resistive load. This is important, and one must adjust the internal lag networks to compensate for whatever residual reactance does appear across the load terminals. This is an adjustment which is common to all the high speed or fast slewing power supplies. In addition, there are the feedback capacitors which have been discussed previously. There are four of them, and adjustment of them is by internal strapping. The last control, internal to the power supply, is called the *current compensator*, a control found on all Kepco automatic crossover power supplies. It adjusts the current regulator to compensate for such shunt conductance loads as the power supply's own voltmeter, as well as the control current of the voltage regulator, and other bleed paths which cannot be removed readily.



SIMPLIFIED DIAGRAM OF THE BHK POWER SUPPLIES WITH REAR TERMINAL CONNECTION DETAILS.

A temperature controlled oven is provided around the precision reference zener diode. This is necessary, because the design philosophy of the Kepco comparison bridge is to *multiply* the reference up to the level of the output, and do the critical voltage comparison on a *one-to-one basis*, rather than *dividing* the output *down* to the level of the reference. This technique enables the power supply to operate without dividing its errors, because there is no division of error, the power power supply can detect millivolt errors resulting in a superlative regulator specification: "0.01% or 1 millivolt, whichever is greater". This *does* impose a great burden on the reference. The reference has to be able to be multiplied without degrading the stability specifications. We have chosen a reflex circuit to feed a stable current to the zener in a precise fashion, so that it is well isolated from the power line, and to enclose that zener in a proportional oven-controlled environment. The current through the zener is maintained extremely constant,

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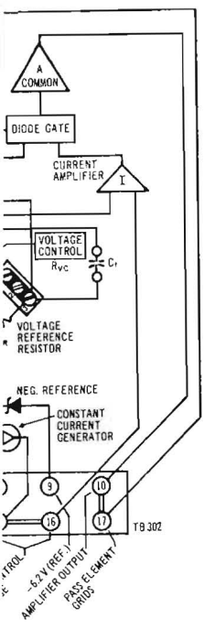

BHK POWER SUPPLIES
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no matter what the output setting of the power supply. This yields a very high grade refcrence indeed.

The BHK power supplies are 19" wide (standard rack), 5¼" high and 16½" deep.The vacuum tubes that dissipate all the heat are at the rear of the power supply, which permits free air circulation, but keeps them physically isolated from the temperature sensitive circuits located near the front panel. There are no blowers, nor is there any need for external forced air.

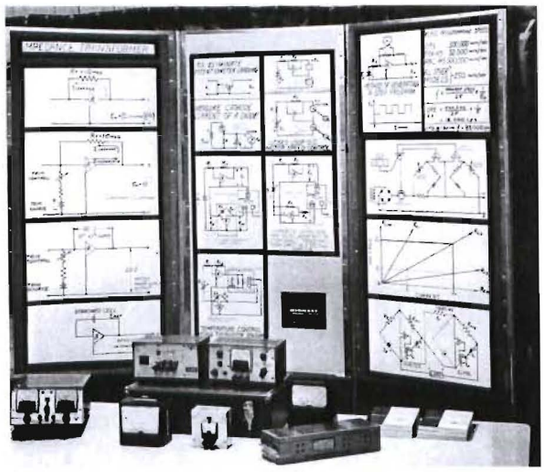
KEPCO-MIDWEST SEMINARS ON TOUR

Continued from Page 1 - Col. 1

The seminars highlight many of the concepts in the Kepco Power Supply Handbook. Following the demonstrations, those attending the seminars find reference to the Handbook easier, more directly meaningful, and are also encouraged to make more sophisticated utilization of Kepco Power Supplies. A personal copy of the Kepco Power Supply Handbook is provided to those in attendance.

Midwest's Bernie Menarik and his associates are frequently invited to present the seminar before groups from just a few, to as many as twenty-five persons.

The seminar, presented in three parts, features a two sided, three partition, aluminum fold-away panel, which effectively displays 24 key block diagrams. Also included as part of the demonstration are five typical Kepco Power Supplies, which are actually in operation, with input or output voltages displayed and loads connected. After a thorough explanation of the patented Kepco bridge circuit, the seminar moves into the operational amplifier concept of programmable Kepco power supplies.



Power Supplies and lecture diagrams used in the Kepco-Midwest Seminars.

Part 1 covers all phases of voltage programming, with emphasis on input impedances, amplifier gain, and summing features. Particular stress is placed on how the operational programming features are realized at full rated output current of the power supply under consideration. Resistance programming follows, with emphasis on how the Kepco supply can be used as a precision voltage reference source.

Part 2 begins by turning and reversing the fold-away display panel, which introduces each subject with simplified operational diagrams. A novel feature of the presentation, for many Kepco users and prospects, is the thorough analysis of how any programmable Kepco power supply can be converted to a unity gain impedance transformer, repeating input voltages at full rated output current. One of the highlights of the demonstration is a standard cell repeater connection measuring only 10-15 nanoamps through a reference voltage cell. This very high impedance and low source current drain, once established, can be used to repeat *any* voltage with current amplification. Various industrial applications are shown where Kepco power supplies utilize external load sensors for "servo-feedback" closed-loop control purposes; for example, motor speed and illumination control, controlled temperature chambers, chemical process control, etc. Actual demonstrations of solar cell and thermistor sensors are shown, with free sample thermistors given to participants.

Part 3 follows with discussion and demonstration of constant current applications, and how they can be effectively employed for laboratory and industrial uses. The seminar concludes with a detailed discussion of programming speeds and various applications which can employ the fast-slewing capabilities of Kepco's expanding line of high-speed programmed power supplies.

If you are in the Indiana, Illinois, Iowa, Kentucky or Wisconsin area, and are interested in having this informative seminar conducted for technical personnel at your facility, please contact your local Midwest Electronic Sales Engineer, or Midwest Electronic Sales, 5707 W. Division Street, Chicago, Illinois 60651. Telephone: 626-0300. Area Code 312. In other areas, contact your closest Kepco technical representative, who has been trained in similar presentations.

B.A. Menarik, Kepco's midwest representative, has been senior partner in Midwest Electronic Sales since 1959. He initiated and developed the Kepco-Midwest Seminar Series described in this article. Since receiving his BS Degree in Electrical Engineering from Notre Dame University, his experience has covered sales, engineering and teaching. He has contributed greatly to the success of the training sessions for Kepco's Sales Representatives held recently in New York.

HANDBOOK DEMAND CONTINUES!

The *Kepco Power Supply Handbook* expounds in several forms the Kepco operational concept for regulated power supplies, treating the signal flow rather than the power flow as a way of better understanding their intrinsic capabilities. With the introduction of the new high speed CK (CK-HS) line of power supplies, and the remarkable BHK group, the applications information in the Handbook is more valuable than ever. If you haven't already obtained a personal copy, write on your company's letterhead to: Publications Manager, Dept. K, Kepco, Inc., G.P.O. Box 67, Flushing, New York 11352.

THE HI-FI POWER SUPPLY *Continued from Page 1 - Col. 2*

In the Kepco HS (high speed), fast slewing, and the unique OPS (operational power supply) designs, elimination of the output and feedback capacitors results in enormously quickened slew rates producing relatively wide usable bandwidth. Speeds from 50 to 500 kilovolts per second (0.05 to 0.5 volts per microsecond) are routinely achieved, with equivalent bandwidths to 20 kc. Bandwidth is a function of excursion, being the slew rate / π *Epeak-peak* (see Figure 1). When the filters are removed from a power supply, other means must be employed to stabilize the high gain amplifier; these take the form of integral adjustable lag networks, without which filter removal is not possible.

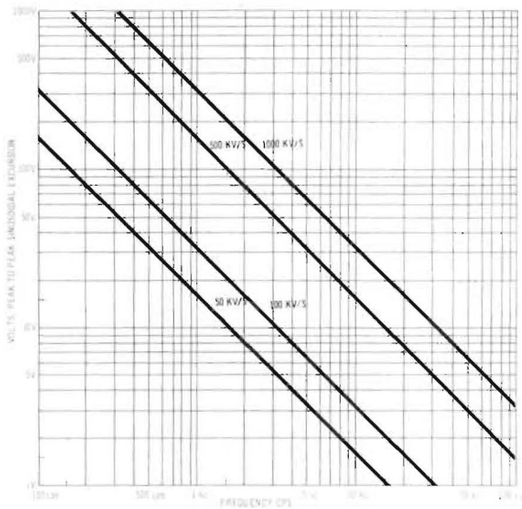


FIGURE 1: DYNAMIC SLEWING TO SINUSOIDAL FREQUENCY CHART

As an operational device, the input resistance of the Power Supply-turned amplifier is an inverse function of the desired gain ratio and is effectively equal to the value chosen for the input resistor (see Figure 2). (Gain equals feedback/input resistance). To adapt an existing high impedance dynamic microphone to this input, a single transistor stage, powered by the supply's own reference voltage (6.2V DC nominal) was constructed for a standard Model PAX 7-1CHS Power Supply, and mounted on the connector plug (refer to Figure 3).

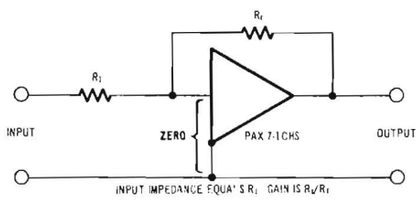


FIGURE 2: OPERATIONAL CONFIGURATION FOR PAX 7–1CHS

The Model PAX 7-1CHS is a high speed power supply module rated 0-7V DC, 0-1 ampere, and is set up as an adjustable gain amplifier with a range 0-1000. The pre-amp stage functioned mostly as an impedance converter, delivering from 0.2 to 0.7 volts peak-to-peak to a 10K input resistor where the appropriate ratio of feedback to input resistance boosts it to a 7V peak-to-peak audio level at the output. To provide sufficient bias (3.5V DC) so that equal positive and "negative" excursions can be handled, a summing resistor is provided between the 6.2V DC reference, and the null junction of the amplifier (see Figure 3).

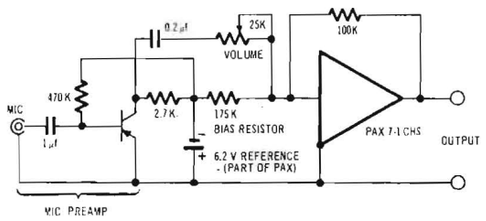


FIGURE 3: MICROPHONE PRE-AMP PLUG-IN ATTACHMENT WITH MODEL PAX 7-1CHS POWER SUPPLY

The output impedance of a Model PAX 7-1CHS Power Supply is a fairly close match for an 8 ohm speaker (7V/1A is 7 Ohms). This is quite different from the usual way of specifying a power supply's output impedance in which the incremental attenuation, or "damping" impedance is specified (a function of the internal inverse feedback). For audio power purposes, the *matching* impedance (for maximum power transfer) is more interesting. Higher output could have been obtained by using a Model OPS 15-1.5C Power Supply whose matching impedance would be 10 ohms.*

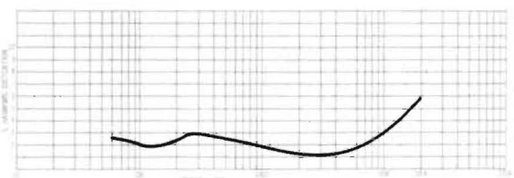


FIGURE 4: % HARMONIC DISTORTION

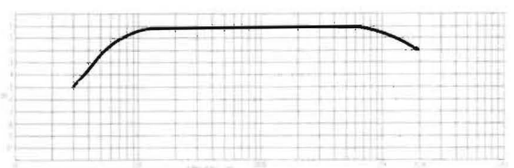


FIGURE 5: FREQUENCY RESPONSE

With microphone and speaker connected, the little PAX gave remarkable performance, filling, on occasion, some pretty good-size auditoriums with clear, undistorted audio. The measured bandwidth and distortion plots are reproduced as Figures 4 and 5. Partly, its good sound comes because of the excellent speaker damping provided by the low incremental impedance (0.02 ohms to 1 kc), plus the lack of low frequency phase shift owing to its DC coupling and lack of output transformer. The only important problem was the DC offset in the

Continued on Page 6 - Col. 1

*Editors Note: The new CK18–3MHS, announced elsewhere in these pages would be a fine match for a 6Ω speaker, also, (18V/3A = 6Ω) with a lot more output.

THE HI-FI POWER SUPPLY *Continued from Page 5 - Col. 2*

speaker cone, resulting from the unipolar nature of the equipment, and its consequent DC bias. This, purists declared, was not at all good for loud speakers (although the sound from ours seemed supremely indifferent to the fact that its voice coil was displaced). To eliminate this objection, a capacitive coupling circuit was devised, consisting of a pair of back-to-back electrolytic capacitors with a pair of clamping diodes to preserve their DC polarity. The diodes permit the use of large electrolytics to preserve a reasonable, low frequency (if not DC) response (see Figure 6).

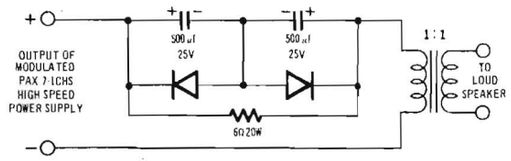


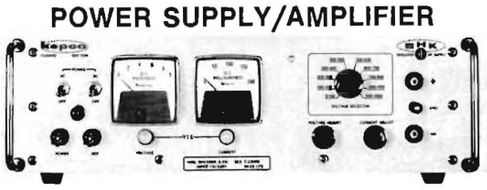
FIGURE 6: COUPLING CIRCUIT FOR LOUD SPEAKER.

When not on loan to run someone's stereo, Kepco's fast slewing power supplies can do some pretty fascinating signal/power processing jobs around most labs. In systems as amplifiers, comparators, sample and hold, integrators, etc., or on the bench serving as fast-responding current source—to avoid the damaging surges of conventionally filtered supplies—the new breed of high speed HS/OPS power supplies provide designers with new latitude and choice.

NEW KEPCO PRODUCTS *for '67*

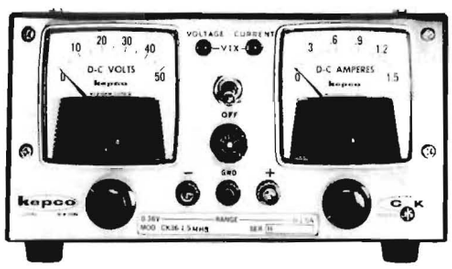
Kepco introduced a number of new products at the recent I.E.E.E. show in New York. These products include advanced concepts in fast slewing Automatic Crossover Power Supply/Amplifiers and applications.

NEW HIGH-VOLTAGE OPERATIONAL POWER SUPPLY/AMPLIFIER



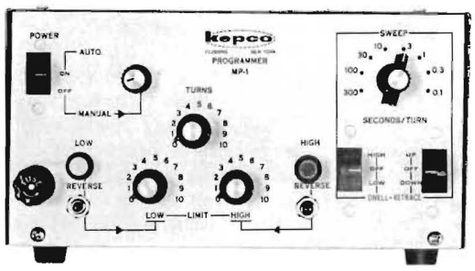
A new series of "BHK" hybrid regulators comprise Kepco's new precision regulated, high voltage *AUTOMATIC CROSSOVER* Power Supply/Amplifiers featuring 0.01% regulation in both voltage and current modes, and equipped with mode indicator VIX* lights. Special terminals are provided to select either a fast slewing mode (for speeds in excess of 0.5 volts per microsecond), or a normal speed power supply mode. The fast slewing mode is particularly useful for current regulation and for applications requiring a wideband, high voltage unipolar DC amplifier. Three models, in the range of 0-500V/0-400mA, 0-1000V/0-200mA and 0-2000V/0-100mA are available. For complete specifications, write for new Brochure #146-1168. (See story on Page 1).

NEW CK HIGH SPEED DESIGN GROUP



A new group of five *HIGH-SPEED* models from the Kepco CK Series provide greatly improved slewing speed and bandwidth characteristics. While standard CK power supplies can be programmed with a maximum slewing speed of 200 to 500V/sec., the five new fast slewing CK models are capable of speeds in excess of 100,000V/sec. This high speed is achieved by eliminating the output filter capacitor and compensating for stability with additional lag networks. The new circuitry emphasizes unipolar DC amplifier characteristics, and provides increased bandwidth for ideal current regulation. For complete specifications, write for new Brochure #146-1168.

NEW MOTORIZED PROGRAMMERS
MECHANICAL FUNCTION GENERATORS



Two mechanical programmers have been made available for scanning resistance controlled functions. Designed primarily to sweep the output of DC power supplies, Model MP-1 operates with sweeps from 1-3000 seconds and Model MP-10 sweeps 10 to 30,000 seconds. Both units operate with a synchronous motor drive through a selectable speed gear box with adjustable end points (limits). Dwells and retrace, plus manual override controls are provided in an attractive "half-rack" package. For detailed specifications, write:

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